METHOD OF FORMING A SPLINED SHAFT

Cross Reference to Related Application

[0001] Priority is claimed under 35 U.S.C. 119 based on U.S. Provisional Application No. 60/449,523 filed February 21, 2003.

Technical Field

[0002] The present invention relates to methods and apparatus for forming splined shafts. More particularly, the method and apparatus of the present invention relate to the forming of splines in shafts and tubes from aluminum alloys.

Background Art

[0003] The forming of a metallic material/metal into a desired shape, by drawing/ rolling over a mandrel, or stamping has been known in the art. With some metallic materials, such an operation often times disrupts the structural integrity of the metallic material. Indeed, many metals and alloys have unstable tempers, which do not lend themselves to downstream permanent deformation via rolling/stamping/drawing. Thus, it has been standard practice to use only metals of certain stable tempers for such operations. Patents in this area include U.S. Patent Specification Nos. 4,766,664; 5,363,628; 5,720,511 and 5,911,844 (Benedyk, Basar et al., Benedyk and Benedyk respectively).

[0004] For instance, in the sheet metal industry, stable, age hardened materials (such as alloys with stabilized -T4 tempers) or fully annealed materials are used in order to achieve maximum formability in stamping or drawing operations. While such materials have been useful, in many applications it is desirous to use an even harder alloy, such as an aluminum alloy having -T6 temper properties.

[0005] In particular, unsatisfactory results have been observed with the drawing/stamping of many types of aluminum alloys (not to mention other metallic materials). For example, a -T4 temper aluminum alloy material is desirable from a ductility and strength standpoint for use in stamping operations. One such advantage is

that it does not need to be solution annealed in order to be able to approach stronger -T6 temper properties in the finished components. The -T4 temper materials need only be aged at moderate temperatures for short periods of time to achieve near or full -T6 temper properties. However, there are drawbacks to using an unstable -T4 temper material in stamping operations inasmuch as the -T4 temper is long-term unstable. Due to its instability, if a -T4 temper material is used to make a component (through a drawing or stamping process) the drawn/stamped region can develop cracks during the drawing operation, and would, if readily formable, be desirous for use in many applications. As such, the component is defective and unusable.

[0006] On the other hand, a -T5 or a -T6 temper aluminum alloy is stable. However, it is difficult to draw or stamp such a material. Indeed, the material is generally too brittle to permit forming through such processes. As such, if any drawing or stamping is attempted with such a material, the material quickly deteriorates and cracks develop. Thus, this material is likewise unsuitable for any such processes.

[0007] It is thus an object of the present invention to provide a method for deforming via stamping, rolling or drawing hard metallic materials that have been conventionally deemed unacceptable for such stamping or drawing.

[0008] It is also an object of the present invention to deform (draw, roll or stamp) such metallic materials at predetermined regions, wherein the predetermined regions have stretched (or drawn) areas having depths greater than conventionally obtainable--without the formation of any visually observable cracking in the stretched/drawn areas.

[0009] These and other objects and advantages of the present invention will be more fully understood and appreciated with reference to the following description.

Summary of the Invention

[0010] The present invention is a method for forming splines on a metallic tube, comprising the steps of: (a) providing a metallic tube having a known hardness corresponding to T4 temper; (b) heating the metallic tube to a temperature sufficient to remove the T4 temper; (c) quenching the metallic tube; (d) forming splines on the

metallic tube; and (e) artificially aging the metallic tube. Preferably the metallic tube is a 6000 series aluminum alloy. T4 temper, as well as other temper designations, is defined as solution heat-treated and naturally aged to a substantially stable condition. Aluminum Standards and Data 1979, The Aluminum Association p.11-14, herein incorporated by reference.

[0011] The invention provides a method for preparing aluminum tubing for forming of a spline geometry for engaging lightweight and simple telescoping aluminum tubes for assembly into torsionally rigid automotive drive shafts and steering shafts with axial compliance. The geometry of the required splines is beyond the forming limits of 6000 (6XXX) series aluminum alloy tubing in the –T4 and –T6 tempers.

[0012] A general inductive heat-treating process for aluminum, known as RHT (retrogressive heat treatment) has been useful for mechanical/compression joining of hollow structural members.

[0013] In contrast, the process of the present invention provides a method of enabling the forming of a complex geometry in telescoping, round aluminum tubular members to precise matching tolerances. The steps include:

(a) providing a drawn or extruded, seamless or non seamless 6000 (6XXX) series type aluminum alloy tube in the –T4 or –T6 temper,

(b) rapidly heating that tube to temperature of 650°F to 1000°F (343°C -538°C) preferably about 900°F to 1000°F (482°C-538°C) using an AC electrical induction coil that covers from only a section to 90% of the length of the tube while maintaining the tube in a stationary position or rotating/ rotating it vertically or horizontally,

(c) quenching the heated tube in water, air, gaseous quenchants or other suitable quenchant, such as a polymer based glycol solution or quenching, to temperatures approaching and to room temperature (about 23 °C), in a carbonated water solution whereby the metal condition/temper after quench is now –W, a state that affords high ductility with low yield strength (a highly

formable condition),

(d) drying the tube, and

(e) subsequently forming or rolling over a mandrel precise, circumferentially applied axial splines along a portion of the tube's(s) length.

The heating may be at only two or more sections of the tube with a non-heated section between them. The quenching may be by immersion, spray or mist quenching. It can be in a tank having a temperature less than about 212°F (100°C). Preferably the splines are formed within 16 hours of quenching if the tubes are stored at room temperature, most preferably within 8 hours of quenching. The quenched metallic tube can be cooled to below room temperature to retard natural aging. If artificially aged, the tube can be heated to at least 300°F (149°C) for at least 5 hours.

[0014] The present invention permits rapid manufacturing of lightweight aluminum telescoping tubes containing rigid, engaging precise splines. Tolerances of +/-0.001 inches or better can be achieved using the present invention.

Brief Description of the Drawings

[0015] Other features of the present invention will be further described in the following related description of the preferred embodiment which is to be considered together with the accompanying drawings wherein like figures refer to like parts and further wherein:

[0016] Figure 1 is a flow chart illustrating the major steps in the fabrication of formed metallic tubes in accordance with an embodiment of the present invention;

[0017] Figure 2 is an illustration of process steps of induction heating using RHT, quenching, and aging metallic tubes in accordance with the present invention; and

[0018] Figure 3 is a cross section view of a splined metallic tube formed in accordance with the present invention.

Mode for Carrying Out the Invention

[0019] The invention provides a method of rapidly resolution heat-treating 6000-

T4 and –T6 aluminum alloy tubing without adversely affecting the grain structure or ability of the material to ultimately achieve its optimum strength for service. Immediately after application of the process the material is in very ductile state in which extensive and precise mechanical forming, i.e., spline forming, can be easily accomplished without fear of cracking, tearing, or undesirable surface roughening of tubing. The resulting matching splines possess a smooth and crack free surface of uniform properties necessary for application of a wear resistant coating of a controlled thickness needed for service use.

[0020] The invention provides a method for preparing aluminum tubing for forming of a spline geometry for engaging lightweight and simple telescoping aluminum tubes for assembly into torsionally rigid automotive drive shafts and steering shafts with axial compliance. The geometry of the required splines is beyond the forming limits of 6000 aluminum alloy tubing in the –T4 and –T6 tempers.

[0021] As Shown in Figure 1, incoming stock 10, straight or swaged, seamless or non-seamless aluminum tubing is passed to a retrogressive heat treating cell 12, an appropriately sized induction coil connected to an RF AC generator, where it passes through a heating phase 14. In the heating phase the induction coil is energized and temperature monitored via thermocouples, infrared devices or temperature sensitive coating. Fig. 2 also shows the induction-heating step 14 where induction coil 16 surrounds the incoming stock 10 and heat, shown by arrows 18, is passed to the stock 10. Then the incoming stock is passed to a quenching stage 20, to undergo vertical or horizontal quenching via air, water, air and water or by other type quenching, also shown in Fig. 2 where water 22 is used to release heat shown by arrows 24. Then the quenched stock is passed to an air or low heat-drying phase 26. Power lines to the RT power supply are shown as 40.

[0022] Splines, shown as 28 in Fig. 3 are formed in step 30 by rolling, drawing or stamping. Here the stock is immediately inserted over a mandrel and axially or circumferentially deformed over a prescribed engagement length to form splines. This is followed by artificially aging to a full hard condition, usually T6, in step 32. Applied heat

is shown in Fig. 2 as arrows 34.

Example

[0023] A cracking problem existed when rolling splines in 6061-T4 tube. Tube diameters involved were 3 ½ and 5 inches in diameter. An RHT treatment was applied to the tubes to achieve local softening and improved formability in the region used to form the splines. Surprisingly, the RHT process permitted 6061and 6013 to be formed, through the standard processing of the spline-rolling machine.

[0024] It is preferable that the metallic tube is an aluminum alloy of the 2000, 5000, 6000 or 7000 series as set forth in Aluminum Standards and Data 1979, The Aluminum Association, pp. 13-14. Most preferably the metallic tube is formed from a 6000 or 7000 series alloy from the group consisting of 6013, 6061, 6063, 7003, 7029 and 7108 as described in International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys, The Aluminum Association, pp 1-10, October 2002, herein incorporated by reference.

[0025] The metallic tube may be a seamless or non-seamless extrusion, a drawn seamless tube or a tube formed from an elongated sheet product that is rolled in a circular configuration, welded to form a tube, and heated in an electric induction furnace. In addition, the metallic tube may be swaged or double swaged to form a tube of multiple diameters and thicknesses.

[0026] What is believed to be the best mode of the invention has been described above. However, it will be apparent to those skilled in the art that numerous variations of the type described could be made to the present invention without departing from the spirit of the invention. The scope of the present invention is defined by the broad general meaning of the above description.